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On the Myxobacteriaceæ, a new order of Schizomycetes.

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(WITH PLATES XXII-XXV.)

A few years since, while collecting fungi at Kittery and in several other localities in New England and the southern states, the writer's attention was attracted by a bright orange-colored growth occurring upon decaying wood, fungi and similar substances, which, although in gross appearance it seemed somewhat highly organized, was found, when examined in a presumably mature condition, to consist of apparently amorphous material, without signs of hyphæ or spores of any kind. Its general appearance and the character of the substance which composed it suggested an immature condition of some myxomycete which had become dried while in the act of rising from the substratum to form its fructification, and on this supposition the material was laid aside until attention was again drawn to it by the occurrence on tree lichens in New Haven, of a closely related organism, which, when artificially cultivated, yielded immature conditions that rendered its true nature apparent. In addition to the two forms just mentioned, the writer has, during the past year, been fortunate in obtaining and cultivating several others having a similar life history, and it is upon these observations that the present paper is based.

This life history, which in several cases has been ascertained by the direct observation of pure cultures made upon sterilized media, is so peculiar, and corresponds so closely, despite the considerable differences which distinguish the more simple from the more highly differentiated forms, and is altogether so unique in the group of Schizomycetes, to which they should undoubtedly be referred, that their separ-

ation as a distinct order seems unavoidable. To the members of this order the writer proposes to give the name MYXOBACTERIACEÆ, for reasons which will become apparent if we consider for a moment the more important stages in their development.

It should first be noted that the life history of these organisms shows a distinct and more or less regular division into two periods; a period of vegetation and, under favorable conditions, a period of fructification or pseudo-fructification: but while the first period is essentially similar in all the forms observed, the second presents remarkable variations.

In the first instance a swarm or collection of rod-like bodies, derived from the successive division by fission of one or more primary individuals, always distinct from one another, possessing a power of slow locomotion and secreting as they multiply a firm gelatinous base which connects the colony as a whole, constitutes the vegetative condition of the organism. This vegetative state continues for a variable but distinct period of time, and in the different forms is characterized by slight variations in the grouping of the individuals composing it. In some cases these may be collected in radiating strands or concentric ridges, or again may be distributed evenly throughout the colony, which in all cases, when growing on a solid medium, possesses a clearly defined advancing edge or border, produced by a heaping up of active individuals in this position. The colony continues to extend itself in this fashion while the conditions remain favorable for its growth; but in the meantime the individuals within this advancing border, having increased rapidly by fission for a certain period, begin to swarm together at different points, often with a characteristic circular tendency in their motion. This piling up of individuals at definite points marks the beginning of the second period just mentioned, which has for its object the production of a resting state.

In the simpler forms, these masses, having raised themselves above the substratum in the form of papillate projections, become rounded off and may be directly encysted without further differentiation. A gelatinous envelope becomes hardened about them to form a protecting wall, within which the encysted individuals are capable of withstanding unfavorable conditions for a protracted period.

From such a simple type as that just described the forms

examined show various degrees of complexity, which reaches its maximum in a most remarkable organism, apparently identical with the supposed fungus described by Berkeley and Curtis under the name of *Chondromyces crocatus*. In this instance we have, following a period of purely vegetative activity, the same swarming together of individuals at different points in the colony; but the masses thus formed, instead of rounding themselves and becoming directly encysted, as in the previous instance, continue to rise vertically from the substratum into the air. The base of the rising mass becomes constricted; the constricted portion is gradually modified into a slender supporting stalk, formed partly of individuals left behind and partly from a gelatinous substance secreted by the mass as it rises. We have then a mass of individuals rising vertically on a slender stalk secreted from its base. This stalk may remain quite simple, or through the division of the mass into two or more lobes, may become successively several times branched, each lobe rising as a distinct mass on a secondary stalk of its own. Finally a condition is reached in which the stem or cystophore, as it may be conveniently called, is terminated by one or more rounded masses of very similar dimensions, in number corresponding to the ultimate divisions of the cystophore, and from these masses arise the cysts which perform the function of reproductive bodies. The cysts first appear as papillate projections covering the surface of each ultimate mass (fig. 4, *a*). The papillæ then become constricted at the base, as the rods composing the mass migrate into them, and assuming at first a fusiform shape, are finally converted in subconical cysts of very regular size and form. The cysts are caducous at maturity, falling from their attachment at the slightest touch, and are disseminated through the air like the conidia of many fungi, which they closely resemble. After a period of rest, and under favorable conditions, the rods make their exit simultaneously from the cyst, leaving behind an empty shell and enter at once upon a new vegetative period; or sometimes, while still *in situ*, proceed to form a secondary cyst (fig. 9, *b*).

Such are the extreme variations in the group, so far as concerns the differentiation of the cyst-producing generation. There appear to be, however, other important differences which divide the forms rather sharply in connection with the

modification of the individual rods at the period of encystment. For while in one group (*Myxococcus*), they become transformed into definite spores, in the other (*Chondromyces* and *Myxobacter*), the rods are encysted as such with little apparent modification, as far as the writer has been able to ascertain.

Without entering into further details of structure or development, which will be found below, sufficient has been said to make intelligible a brief comparison between the course of development of these plants and that of other organisms which may seem to possess certain characteristics in common with them.

The general character and structure of the rod-like individuals, together with their vegetative multiplication by fission, renders their schizomycetous nature as individuals a matter hardly to be doubted: but, on the other hand, the question may fairly be asked whether the remarkable phenomena which they present, not as individuals, but as aggregates, may not indicate a possible relationship in other directions. In the account just given it is hardly necessary to point out the evident similarity between the course of development described and that which occurs in the Mycetozoa, and more particularly in the Acrasieæ. In no other group, as far as the writer is aware, does there exist a similar concerted action of aggregates of individuals towards a definite end, namely, the production of a more or less highly differentiated resting state. Setting aside for the moment the fundamental differences presented by the cell characters in either group, the vegetative condition of the Acrasieæ and that of the Myxobacteriaceæ may be considered strictly comparable. In both cases multiplication by bipartition, followed by the complete separation as individuals of the two parts thus formed is followed in turn, after a period of successive bipartitions, by a swarming together of distinct individuals into aggregates of distinct individuals having a definite end in view. Apart from differences of cell structure, therefore, the essential characters of a pseudo-plasmodium are common to both groups.

Following the analogy to later stages of development a certain similarity may be noted between the steps which lead in either case from the simpler to the more complicated forms. In both instances a transition is observable from a mere heap-

ing together of individuals to form a resting state, to the production of a similar state, developed in a more complicated fashion and raised upon a highly differentiated stalk, through intervening forms, in which this stalk appears merely as a supporting base.

The most essential discrepancy which is apparent in such a comparison rests on the fundamental difference in cell structure already referred to, since although the Acrasieæ have taken a decided step away from the true Myxomycetes in the production of cells which neither coalesce nor produce pseudopodia (as in the Guttulinaceæ), the step from such amœboid cells to definite rods having all the characteristics of typical schizomycetous cells is, to say the least, a very long one. This fundamental difference necessarily involves equally important differences connected with the modification of individuals, in either case, while in the resting state, even when a definite spore formation takes place in both instances; while the encystment of numerous individuals to form a spore-like body, in the manner above described, presents an additional point of deviation in this connection.

In view of such important differences, the writer would hesitate to assume even a remote genetic connection between the two groups on a basis of resemblance which might well be purely accidental. Yet it is a question to which further investigation in this direction may afford a more definite answer, whether the evidence at hand may not show the necessity of still greater caution in accepting the views of those who would unceremoniously relegate the Mycetozoa to the domain of pure zoology: since, other matters apart, we find in the present order a characteristic at least very similar to that which has been held to constitute a crucial difference between the Mycetozoa and any known group of *plants*, namely, the occurrence in their developmental history of phenomena closely resembling those presented by plasmodia or pseudoplasmodia—not an indiscriminate heaping together of individuals as a result of merely vegetative processes, but a definitely recurring aggregation of individuals capable of concerted action towards a definite end, an end which finds its accomplishment in the production of a more or less highly developed resting state.

Whatever its true affinities may prove to be, however, the order is undeniably a very interesting and important one,

and although the present account is necessarily incomplete, it may serve to call attention to a subject which, beyond question, offers a productive field for further investigation.

Historically the story of the group is not a long one, yet is instructive in showing the absurdities to which the careless and wholesale description of new species may lead. *Chondromyces aurantiacus*, for example, has, if the writer's conclusions are correct, been placed in three separate genera of hyphomycetous fungi, although possessing no trace of hyphæ or of spores, the slight striation of the shrunken cystophore in the one case and the general external appearance of the cysts or of their contents in the other, having been made to assume these functions for descriptive purposes. The same is also true to a less degree of *C. crocatus*, although from its apparent rarity it seems to have escaped an extended synonymy. Whether any of the other forms enumerated below have been previously described the writer is unable to say; yet it seems very improbable that the spores of such common and conspicuous forms as *Myxococcus rubescens* and *M. virescens* should have escaped description, at least as chromogenous micrococci. The species of *Cystobacter* Schröter seem with little doubt to belong to the present family, and should probably be referred to *Chondromyces*, possibly *C. aurantiacus*, which in artificial cultivation produces a variety of abnormal forms and becomes "kastanien braun" when kept moist for a certain period. The descriptions of Schröter, however, are not sufficient to render any definite conclusion possible in the absence of proper figures.

MYXOBACTERIACEÆ.

Motile, rod-like organisms, multiplying by fission, secreting a gelatinous base, and forming pseudoplasmodium-like aggregations before passing into a more or less highly developed cyst-producing resting state, in which the rods may become encysted in groups without modification or may be converted into spore masses.

GENERAL CHARACTERS.—The vegative rods present but slight variations in size and form in the different genera and species. In all cases they are typically elongate, sometimes attaining a length of 15μ and, while living, show a tendency to taper slightly towards either extremity which disappears when they are killed, the ends becoming

bluntly rounded. The cell wall is highly elastic and surrounded by a barely perceptible gelatinous layer, while the cell contents may usually be seen to contain distinct granular masses (fig. 27, *a*) of irregular size and shape which stain more deeply than the remainder of the cell. Cell division follows an elongation and nearly median constriction of the rods which, except at the moment of division, are always separate, never united in chains. A slow, though distinctly visible movement characterizes the active rods and consists in a sliding locomotion in conjunction with a lateral bending. This lateral movement, which may take place in any plane, may be carried to such an extreme that the rod may form a loop with its ends approximated, after which the normal straight position may be assumed with considerable rapidity. This bending movement is doubtless an important factor in the sliding locomotion which though barely perceptible, can be definitely ascertained by careful watching.

The grouping of rods in a colony may vary somewhat in different species and under different conditions. In *Chondromyces aurantiacus*, for example, they may, when growing in a semi-liquid medium, show a tendency to radiate from a common center in rope-like, anastomosing strands, while on a solid medium these strands may form ridges, the alternate elevations and depressions in which may give the colony a characteristic corrugated appearance. In other cases, as for example in *Myxococcus*, the rods may show less tendency to collect together, remaining more or less evenly distributed until just before the period of spore formation. In all cases the individuals of a colony are heaped together in the region of its advancing margin which is distinctly elevated above its surroundings, and characteristically roughened by great numbers of partly free individuals projecting from its surface. In all species, with one exception, the rods when seen in masses, are more or less distinctly reddish. This color may, however, be lost as the mass rises to form cysts, as is the case in *C. crocatus* as well as in *Myxobacter aureus*.

A distinct, firm, hyaline, gelatinous base is secreted by the colony as it extends itself, over which the individuals may move or in which they may become imbedded, and is so coherent a structure that whole colonies may be stripped intact by means of it, from the surface of nutrient agar, for example. At the period of cyst formation it is often left

behind as a distinct shining membrane in which a few rods remain here and there imbedded.

The duration of the vegetative period varies according to circumstances. In artificial cultures it usually lasts about a week or even two weeks; but in nature the production of cysts must certainly be more rapid. In *Chondromyces lichenicolus*, for example, a period of moist weather following continued drought, and lasting not more than two or three days is sufficient to cover the previously dry tree trunks on which it vegetates with large patches of cysts.

The preparations for the production of cysts are apparent to the naked eye in artificial cultures of *C. crocatus*, for example, about a day before the cystophores begin to rise. In this condition the colony even in the neighborhood of its advancing edge, assumes a lumpy appearance owing to the aggregation of rods at various points. In forms like *Myxococcus*, in which the rods are somewhat scattered, the first preparation for spore production as seen under the microscope consists in the appearance of groups of rods moving with a circular tendency and forming whirlpools, so to speak, in which the more central individuals soon become converted into spores, the successive formation of which results in the production of the elevated spore masses characteristic of the various forms.

The formation of a cystophore where it occurs results from the basal constriction of a papillate mass of rods which projects from the surface of the colony. The mass of rods moving upwards on one another, continually leaves behind and below it an external layer at its base which has become slightly hardened by exposure to the air and is composed partly of the gelatinous matrix, partly of individuals which soon become indistinguishable in it. As the mass rises within and above this slightly hardened layer, the latter, while being constantly renewed above, becomes contracted below to form the cystophore. The cystophore may therefore be compared during its formation, to a glass funnel, the flaring portion of which is being constantly renewed from the outer surface of the mass of rods contained within and rising above it, while the tubular portion is being constantly lengthened by the contraction of the flaring portion at its base. As the freely moving individuals pass up out of the upper portion of this tube it is left behind as a gelatinous structure which becomes

indurated and solid, its strength being often further increased in slender forms by a decided spiral twist.

This primarily tubular character of the cystophore is well shown in specimens of *C. aurantiacus* when cultivated with very moist surroundings. In such cases even after the cystophore has attained its full height a central clearly differentiated column of active individuals may be seen moving up to the cysts which are in process of formation at its summit (fig. 13). In its development the cystophore shows all degrees of complexity from the short supporting base (which may be wholly absent) of *C. lichenicolus*, to the elongate form in *C. crocatus* which may produce branches of the fifth or even sixth order.

In considering the encysted condition of these organisms, two distinct categories are recognizable in connection with this state, one in which the individuals thus encysted show little or no modification from the rod-like vegetative state, the other in which they are converted into definite spores.

In the first instance the form of the cyst varies considerably presenting in the genus *Chondromyces* the series illustrated by *C. serpens*, *C. lichenicolus*, *C. aurantiacus* and *C. crocatus* (figs. 24, 23, 22, 15, 14 and 6) and may be further modified by a more or less complete fusion of adjacent cysts originally distinct (figs. 24, 23, 16). This fusion may result in the anastomosing coil characteristic of *C. serpens* or may consist in a mere lateral adherence of two neighboring cysts as in *C. crocatus*. The degree of encystment also shows considerable variation in the series just mentioned and reaches its highest development in *C. crocatus* in which the distinction between cyst wall and cyst contents is clearly marked. The cysts of *Myxobacter* present an additional peculiarity in that the very large thick walled cysts are themselves involved in a gelatinous matrix which dries in the form of a tough general envelope.

The substance of these cysts, composed partly of rods and partly of a firm and surprisingly coherent matrix, appears at maturity even when examined under a high power of the microscope, to be composed of stringy amorphous matter which is separated by crushing with the greatest difficulty. It is only by the closest examination and the use of staining agents that the presence of any definite bodies whatever within such cysts can be made out. Here and there the closely adhering

rods may be separated and isolated by crushing; and in this condition they show little modification from the vegetative state except that they are somewhat shorter and thicker. In a few cases rods have been observed within the cysts in stained preparations in which an apparent differentiation of the rod contents was observable. Whether this appearance was due to the presence of spores or merely indicated an accidental aggregation of the granular cell contents was not determined.

For a short time after the cysts are mature and also before they germinate after a period of rest, the contained rods are clearly defined and do not adhere closely to one another. The contents of such a cyst when crushed makes its exit as a mass of distinct rods somewhat shorter and thicker than the vegetative forms.

In "germination" the cysts emit their contents in a continuous stream which finally leaves the cyst wall as an empty shell, the emission being effected through the absorption of a portion of the cyst wall, usually at the base in the spore-like forms, sometimes at the apex or elsewhere. The mass of rods thus freed begins at once to vegetate, the individuals dividing rapidly and entering upon a new period of activity. Exceptions to this course are often found in old cultures of *C. crocatus* where cysts that have germinated *in situ* at the tips of the cystophores may frequently be seen producing secondary cysts directly, which are borne on short, slender secondary cystophores (fig. 9), a circumstance which still further illustrates the remarkable though superficial resemblances which exist between these forms and higher fungi.

In the sporiferous species, which have been included in the single genus *Myxococcus*, there may be a general encystment of the spore mass into a definitely formed coherent structure, as in *M. coralloides*, or this structure may normally become soft and semi-fluid through the deliquescence of the gelatinous matrix in which the spores are imbedded, as in *M. rubescens* and *M. virescens*. The spores are more or less irregularly spherical refractive bodies, the diameter of which is much greater than that of the rods from which they are derived, the difference being most remarkable in *M. rubescens* and *M. virescens*. The method by which the spores are derived from these rods has not been ascertained by continuous observation, since sporulation only takes place at the period when

the rods swarm together for this purpose and then only in the central region below the rising mass of spores which, together with the aggregation of rods around it, completely conceals the details of transformation when viewed directly under the microscope. By crushing such masses, however, the steps by which the spore-production is effected may be inferred from the occurrence, here and there in the swarm of unmodified rods and spores thus separated, of forms similar to those represented in fig. 40. Such forms would indicate that the rod, by division following simultaneous or successive enlargement throughout its whole length, is directly converted into spores varying in number according to the length of the rod; and in the absence of any indication of a different process this may be assumed to be correct. This conclusion is further supported by the very frequent occurrence in such preparations of chains of spores adhering in twos, threes or even fives (fig. 41).

The germination of these spores has not been observed to the writer's satisfaction; but appears to consist in a gradual transformation from the round to the rod-like form. Whether an external membrane is left behind in this process could not be determined.

The nine species which constitute the family so far as at present known, may be arranged under three genera, as follows:¹

CHONDROMYCES B. & C. (1857), in Berk. Introd. Crypt. Bot., p. 313, fig. 70, a (no descr.) 1857. do. in Grevillea III. p. 64 (first descr.) 1874.

Stigmatella: B. & C. in Berk. Introd. Crypt. Bot., p. 313, fig. 70, b (no descr.) 1857. do. in Grevillea III, p. 97 (first descr.)

? *Polycephalum*: Kalch. & Cke. in Grevillea IX, p. 22, 1880.

? *Cystobacter*: Schroeter in Kryptogamen-fl. v. Schlesien III, I, p. 170.

¹ NOTE.—In considering these forms from a systematic point of view the writer has preferred to avoid the multiplication of genera and species; since the true value of generic and specific distinctions in a group so little known in these respects, is a matter which can only be settled satisfactorily by a wider knowledge of the remaining forms, which undoubtedly exist. For this reason it has not been thought advisable to separate generically members of the series included under *Chondromyces*, the connection between the extreme forms (*C. crocatus* and *C. serpens*) being so well illustrated by the remaining species. Again, the deliquescent guttulae which constitute the spore masses of *Myxococcus rubescens* and *M. virescens* and the definitely coherent structure found in *M. coralloides* are very different in character, yet in the absence of further data as to species a generic discrimination of these forms seems inadvisable. The writer recognizes the fact, however, that further information may modify the arrangement adopted not only in regard to genera and species, but also in connection with the division of the groups as a whole, which might properly be divided into two definite sub-families based upon the peculiarities of the resting condition.

Rods forming free cysts, in which they remain unmodified. Cysts various, sessile or borne on a more or less highly developed cystophore.

CHONDROMYCES CROCATUS B. & C. Plates XXII, XXIII, figs. I-II.

Chondromyces crocatus: B. & C. in Berk. Introd. Crypt. Bot. p. 313, fig. 70, a (no descr.) Berkeley in Grevillea, III, p. 64 (descr.) Cooke in Bull. Buff. Soc. Nat. Sci. III, p. 192. Saccardo, Sylloge Fungorum IV, p. 576.

Aspergillus crocatus: B. & C. in herb. Curtis, and herb. Berkeley (sec. Farlow).

Colonies pale orange red. Rods cylindrical or tapering slightly straight or slightly curved, $2.5-6 \times .6-.7\mu$. Cystophore orange colored, slender, simple or 1-5 times successively branched, striate, spirally twisted or irregularly bent; average height 600μ , rarely 1 mm. Cysts pale straw colored, at first fusiform, at maturity sub-conical, rounded at the apex, often ragged at the base. Average dimensions $28 \times 12\mu$ ($15-45 \times 6-20\mu$), in variable numbers at the tips of the cystophore where they form globose heads, $70-90\mu$ in diameter.

South Carolina, *Ravenel*, in herb. Curtis and herb. Berkeley, on decaying melon rind. Cambridge Mass., on old straw.

The specimens of this plant in the Curtis collection correspond in all respects with the Cambridge material which made its appearance on some old straw sent from Ceylon, and has been kept in cultivation in the laboratory, growing readily on nutrient agar and luxuriantly on sterilized horse dung. According as the substratum is moist or dry the general habit may vary considerably, excessive moisture often producing considerable irregularity in the form and number of the cysts as well as in the cystophore, which is thicker under these conditions, more irregularly branched and without the spiral or longitudinal striations (due to wrinkles of the surface) usually characteristic of the slender forms.

Cultures of the cysts in Van Tieghem cells have yielded few germinations after several months, but it may be readily observed by placing in a moist chamber a specimen which has been kept dry. By examining such a specimen after one or two days the germinating cysts may be seen in all conditions. At first the contents becomes slightly contracted within the cyst-wall and in it the separate rods may be distinctly seen; then through the absorption of the wall usually at its base, the rods are allowed to make their escape in a continuous stream till nothing but the empty cyst-wall is left behind.

The mature cysts show none of the reddish coloring pecu-

liar to the other species, and as in *Myxobacter aureus* this seems to be lost as the rod-masses rise to produce cysts. Although so conspicuous a form, this species does not appear to have been recorded since its discovery by Ravenel, Cooke and Saccardo merely quoting Berkeley's publication in the references above cited. As a matter of curiosity Berkeley's description is appended.

"*Chondromyces* B. & C. Stipes e floccis compactus ramosus induratus, sporæ apicales.—600. *Chondromyces crocatus* B. & C. On decayed melons. Car. Inf. no. 1335. Stem closely compacted, orange, subcartilaginous, branched, the branches more or less divaricate, nodular at the apex; spores elongate-ovate with a very short pedicel." Grev., *l. c.*

CHONDROMYCES AURANTIACUS (B. & C.)—Plates XXIII, XXIV, figs. 12–19 and 25–28.

Stigmatella aurantiaca: B. & C., in Berk. Intr. Crypt. Bot., p. 313, fig. 70, b. do. Grevillea, vol. III, p. 97. Cooke, Bull. Buff. Soc. Nat. Sci., vol. III, p. 193. Curtis' Cat., p. 126. Saccardo Sylloge Fung., iv, p. 680.

? *Polycephalum aurantiacum*: Kalchbr. & Cke. Grevillea ix, p. 23, pl. 135, fig. 10, a, b, c. (1880). Saccardo Sylloge Fung. iv, p. 576.

? *Stilbum rhytidospora*: Berk. & Broome, on the Fungi of Ceylon, Jour. Linn. Soc. (Botany) xiv, p. 96, plate iv, fig. 16 (1873). Sacc. Sylloge iv, p. 571.

Colonies flesh colored, distinctly reddish. Rods large, tapering somewhat, normally straight, rounded at either extremity $7-15 \times .6-1\mu$, average $7 \times .5\mu$. Cystophore hyaline or flesh-colored, stout, straight, simple or rarely furcate. Average height 200μ . Cysts at first stalked, then sessile, oval to elliptical or rounded in outline, often irregular in size and shape, bright orange colored when dry, becoming chestnut brown when kept moist for a considerable period, borne in variable numbers and forming globose heads at the extremity of the cystophore. Cysts about $30-50 \times 30-75\mu$.

S. Carolina, on *Sphæria Hibisci* (herb. Curtis). N. Carolina, Connecticut to Maine, on decaying wood and fungi.

With the exception of *Myxococcus rubescens* this is the commonest member of the group and must have been met with by any one who has sought for Myxomycetes on decaying wood, where though very minute it is conspicuous from its bright color. Although easily cultivated on nutrient agar, unlike *C. crocatus* it rarely produces well formed cystophores and cysts on this medium, though cultivable on its ordinary substrata without difficulty.

In giving its synonymy, *Polycephalum aurantiacum* K. & Ck. as well as *Stilbum rhytidospora* B. & Br. have been included

with a query. The description and figures given in either case leave little doubt of the correctness of this reference, but a comparison of authentic specimens has not been made. Whether one or both of the forms described by Schroeter under *Cystobacter* may not prove abnormal conditions of this species is also uncertain; but on very moist media it shows conditions closely resembling his descriptions, and becomes chestnut brown after continued exposure to moisture, thus presenting an additional point of resemblance. Even in its natural substratum cyst formation is subject to great irregularities, especially if the rising rod masses become slightly dry during the process. In such cases the latter may heap themselves together in irregular cyst masses lying directly upon the substratum with little or no differentiation of a cystophore.

The genus *Stigmatella*, which was founded upon this species, is made by Saccardo to include two species, *S. aurantiaca* and *S. pubescens* Sacc. & Ell., the latter having been formerly described under the name *Sphærocreas pubescens* Sacc. & Ell. (*Michelia* II, p. 582.) Although Saccardo remarks concerning this form, "De identitate *Sphærocreatis* cum *Stigmatella* nullum mihi est dubium," it is difficult to see on what this opinion is based; the fungus in question consisting of a rounded mass of large chlamydospores borne terminally on well defined hyphæ and surrounded by a woolly mass of somewhat differentiated hyphæ. It is needless to remark that the two can have no connection, *Sphærocreas* being clearly a fungus allied to if not generically identical with forms included in the genus *Endogone*.

Chondromyces lichenicolus n. sp.—Plate XXIII, figs. 20–23.—Colonies reddish, rods cylindrical, tapering slightly, $5-7 \times .6\mu$. Cystophore simple, short, squarish, often absent or ill developed, $7-8 \times 10\mu$. Cysts single, rounded or irregularly lobed, often confluent, bright red, $35 \times 28\mu$.

Parasitic on living lichens, which it destroys, New Haven, Ct.

This species has not been met with in any locality other than the one mentioned, where it occurs abundantly on the trunks of the elms and maples along the city avenues, often covering patches several feet in length. The cysts are very irregular in form, often lobulated and laterally confluent, and their crowded habit and deep red color make them very conspicuous. Owing to the shortness of the cystophore, it is seen

with difficulty *in situ*, and seems often to be wholly absent. Specimens kept dry in the herbarium for eighteen months germinate readily when sown on moist lichens, and like other cysts of the group would probably retain their vitality for a much longer period.

Chondromyces serpens n. sp.—Plate XXIV, fig. 24.—Rods as in *C. lichenicolus*. Cysts flesh-colored, dark red when dry, 50μ in diameter, confluent in an anastomosing coil. Cystophore absent.

On decaying lichens, Cambridge, Mass.

This species made its appearance in company with *C. lichenicolus* in a laboratory culture and was at first taken for an abnormal condition of that species. Cultures on agar and on lichens, however, constantly produced the same convoluted form which seems to be quite distinct and differs from all the remaining species of the genus in possessing no cystophore, the mass being sessile upon its substratum, and often reaching a length of more than a millimeter.

MYXOBACTER n. gen.—Rods forming large rounded cysts, one or more free within a gelatinous matrix raised above the substratum.

Myxobacter aureus n. sp.—Plate XXV, figs. 34–36.—Colonies when rising to form cysts milky white. Rods large, cylindrical, rounded at either end, $4-7 \times .7-.9\mu$. Cysts spherical or oblong, golden yellow, thick walled, one to twelve or more in number, distinct within a hyaline matrix, $75-350 \times 75-275\mu$. The encysted rods mingled with a yellow, oily material. Cyst groups .7–1 mm. long.

On very wet wood and bark in swamps. Kittery Point, Me., Belmont, Mass.

MYXOCOCCUS n. gen.—Rods slender, curved, swarming together after a vegetative period to form definite, more or less encysted sessile masses of coccus-like spores.

Myxococcus rubescens n. sp.—Plate XXV, figs. 37–41.—Rod-masses reddish, rods slender, irregularly curved, $3-7 \times .4\mu$. Spore masses scattered, drop-like, flesh-colored to dull orange, deep crimson when dry, at first coherent, becoming deliquescent, $150\mu-1\text{ mm.}$ in diameter, often confluent. Spores round, $1.5-1.2\mu$ in diameter.

On various decaying substances, lichens, paper, dung, etc. This species is so common and makes its appearance with

such constancy on laboratory cultures of horse dung that it seems hardly possible it should have escaped previous description as a chromogenous coccus. The only form which has been described on this substratum to which it could possibly be referred is *Micrococcus fulvus* Cohn¹. This species appears however, to be a true *Micrococcus* and, judging from the specimen in Rabh. Alg. Eu. no. 2501, bears little resemblance to the present form. The drop-like masses are at first more or less coherent and may be transferred intact to a slide for examination; but they soon become deliquescent, adjacent guttulæ coalescing into viscous masses more than a millimeter in diameter. The variation from flesh-color to orange-red forms may indicate an additional species, the orange type retaining this tint in agar cultures without varying towards the flesh-colored form. The morphological differences if there are any, are, however, too slight to warrant a specific distinction.

Myxococcus virescens n. sp.—Rod masses greenish yellow. Rods as in *M. rubescens*. Spore masses clear yellow-green to green, 150–500 μ in diam. Spores round, 1.8–2 μ in diam.

On hen's and dog's dung, New England.

This species, which closely resembles the last except in color, is rather rarely met with on the substrata mentioned, forming rather smaller spore masses. When cultivated on potato agar it tends to lose its green color and become yellowish. The spores seem constantly larger than in the preceding species.

Myxococcus coralloides n. sp.—Plate XXIV, figs. 29–33.—Rod masses pale pinkish, thin. Rods slender, curved, 4–7 \times .4 μ . Spore mass firmly coherent, erect, variously branched or lobed, the lobes or branches usually tapering towards the rounded apex, flesh-colored, becoming bright pinkish when dry; maximum height 350 μ , the lobes about 20–30 μ in diameter. Spores spherical, 1–1.2 μ in diam.

On decaying lichens, Cambridge, Mass.

This striking form made its appearance in laboratory cultures and was readily cultivated on lichens and potato agar. The coral-like form of the spore mass is very variable, presenting every imaginable variation from a simple papilla to a complicated structure similar to that represented in fig. 29.

In addition to the species above enumerated the writer has observed several others, among them a very minute and peculiar

¹Cohn: Beitr. z. Biol. d. Pflanz. 1, 3, p. 181.

form occurring on rabbit's dung, belonging to the *Myxobacter* group, and another on lichens near *Myxococcus coralloides*, but was unable at the time to observe any of them under cultivation. Further additions to the order are therefore certainly to be looked for.

Cryptogamic Laboratory of Harvard University.

NOTE.—*Myxobacter simplex* n. sp., for which I accidentally omitted to send manuscript will be characterized in the succeeding number.

EXPLANATION OF PLATES XXII-XXV.

The figures are drawn with few exceptions from specimens mounted in glycerine. The combinations used are as follows: Figs. 1-6, 12-16, 20-21, 24, 29, 34: Zeiss oc. 4, obj. A. Figs. 7-10, 17-19, 22-23: Zeiss ocul. 4, obj. D. Figs. 11, 26-28, 31-33, 35-36, 39-41: Zeiss comp. oc. 12, Leitz oil im. $\frac{1}{2}$. Fig. 31: Zeiss oc. 4, Leitz oil im. $\frac{1}{2}$. All figures reduced $\frac{1}{4}$ by photo-lithography.

PLATE XXII.

Chondromyces crocatus (B. & C.)

Fig. 1-6 successive conditions of cyst formation shown by as many individual specimens. Fig. 1. *a*, mass of rods just rising from substratum and becoming constructed at its base. *b*, smaller mass which has begun to secrete a cystophore and has become two-lobed preparatory to branching. Fig. 2. A more advanced specimen, the mass preparing to produce three branches. Figs. 3, 4. Nearly mature cystophores showing branching of the third and fourth order, the ultimate masses beginning in some instances (*a, a*) to bud out into cysts. Fig. 5. Specimen cultivated on moist agar, the cystophore unusually stout, the ultimate masses almost wholly converted into immature cysts. Fig. 6. Specimen grown on straw showing normal habit; the cysts not yet mature.

PLATE XXIII.

Chondromyces crocatus (B. & C.)

Fig. 7. Optical section of ultimate rod mass from which the rods have for the most part migrated into the immature cysts. Fig. 8. Three ultimate branches of a cystophore, one of them with three mature cysts still *in situ*. Fig. 9. Tip of an ultimate branch of a cystophore on which two cysts still *in situ* have germinated to produce secondary cystophores and cysts (*a, a*). Fig. 10. Five detached mature cysts showing extremes of size under ordinary conditions. Fig. 11. Vegetative rods.

Chondromyces aurantiacus (B. & C.)

Fig. 12. Young cysts budding from apex of cystophore. (Living material.) Fig. 13. A more advanced stage, a central column of ascending rods surrounded by a gelatinous layer. (Living material.) Fig. 14. Three specimens from dried material one showing terminal rod-mass from which the cysts have not yet begun to bud. Fig. 15. Specimen from dried material showing furcate habit. Fig. 16. Mature specimen from dry material in which the cysts show lateral coalescence. Fig. 17. Three mature cysts. Fig. 18. Two cysts kept on moist wood for several weeks, preparing to germinate. Fig. 19. A similar cyst germinating.

Chondromyces lichenicolus n. sp.

Fig. 20. Mature cysts on short cystophores. Fig. 21. Rod masses rising to form cysts. Figs. 22-23. Mature cysts with short cystophores, showing lobulation and coalescence.

PLATE XXIV.

Chondromyces serpens n. sp.

Fig 24. General habit of coalescent cysts.

Chondromyces aurantiacus (B. & C.)

Fig. 25. General appearance of a portion of rod mass growing in fluid agar. Fig. 26. Living rods from active rod-mass. *a*, rod dividing. Fig. 27. Vegetative rods in glycerine (*a*) showing granular contents stained with borax carmin. Fig. 28. Rods isolated in mature crushed cysts.

Myxococcus coralloides n. sp.

Fig. 29. Highly developed spore mass. Fig. 30. Spore mass of a different form more highly magnified. Fig. 31. Spore mass rising from rod mass at its base. Fig. 32. Vegetative rods. Fig. 33. Mature spores. *a*, spores in process of formation.

PLATE XXV.

Myxobacter aureus n. sp.

Fig. 34. General habit showing four cysts embedded in gelatinous matrix. Fig. 35. Rods (living) from rising rod-mass. Fig. 36. Rods from cysts crushed at maturity.

Myxococcus rubescens n. sp.

Fig. 37. General appearance of young spore mass viewed from above and surrounded by vegetative rods. Fig. 38. Normal habit of spore mass viewed laterally. Deliquescence beginning at the top. Fig. 39. Vegetative rods. Fig. 40. Different stages of supposed spore formation. Fig. 41. Mature spores.

Development of the flower and embryo-sac in *Aster* and *Solidago*.

G. W. MARTIN.

(WITH PLATES XIX AND XX.)

Concluded from page 358.

Let us now turn to the development of the ovule and the embryo-sac. A short time before the floral organs attain their maximum length, there appears at the bottom of the ovarian cavity a rounded excrescence; this is the incipient ovule, the promise of a future seed (fig. 11).⁶ This incipient ovule does not arise from the bottom of the ovarian cavity, but a little above the lowest point. Therefore, the ovule is not the terminal structure on the floral axis. For, by careful focusing, the apex of the fascicular system is seen to end very abruptly at the bottom of the ovary cell. To the right and left of the axial bundle of the pedicel, a little below the apex, are given off fibro-vascular bundles which traverse both sides of the carpellary leaf. It is in the region of one of these lateral bundles, beneath the epidermis, that the primitive cells develop, which arch upward and give rise to the funiculus and the nuclear ovule. Subsequently, a branch of this lateral bundle

⁶The ovule somewhat advanced.